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RESEARCH ARTICLE **OPEN ACCESS**

RICE HUSK ASH: A SYSTEMATIC REVIEW OF ITS APPLICATIONS

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ABSTRACT

In recent years the agricultural waste or by-products has received increasing attention in the economic, scientific, social and technological areas. Rice husk (RH) is a by-product of rice milling and rice husk ash (RHA) is obtained by burning of rice husk in boiler. RHA, consists of large amount (approximately 85–95%) of amorphous silica. In past few years RH and its ash has been utilized extensively in different fields for synthesizing different materials and in wide variety of applications. The silica obtained from RHA or RH provides a potential substitute to conventional silica for the synthesis of many value-added products. This paper reviews the composition and application of Rice husk and Rice husk ash in various fields.

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INTRODUCTION

Nowadays agricultural waste has found widespread application in various fields. Due to low prices of these waste, it is very difficult to estimate the exact amount of these waste. There economic value are very low even lower than the cost of gathering, transportation and processing for various application. As per the report biomass is responsible for producing around 9% of global energy ie biomass used as fuel or get converted into solid fuel. Agricultural waste consists of harmful agricultural waste i.e. herbicide, insecticide and pesticide, fruit and vegetables, food processing waste etc. Rice husks is one of the major source of value added material towards utilization of waste and is directly responsible for cost reduction in various processing industries as well as domestic applications. In all the rice producing countries Rice Husk (RH) is easily and almost freely available, as it is by-product of the rice milling. Rice husk composition include around 16-25% of paddy (Giddel.,2007; Soltani,2015). Every year more than 120 million tonnes of rice is produced in India, which contributes near to 24 million tones of Rice Husk every year and it is found that this number is increasing day by day. Rice husk ash (RHA) is the one of the major by-product of rice husk burning. Rice husk ash is obtained when husk is burnt in ambient temperature and pressure condition. It has been reported that around 20 million tonnes ash is produced per year around the world (Soltani *et al.*,2015, Koteswara and Pranav, 2011).Handling of this Rice husk is a big problem because of its low density and less commercial interest. Transportation of this husk is also problematic, and its creates various problem related to its disposal and when it is burnt it field it creates serious environmental issue (Pode, 2016). Rice husk has very high value applications such as it is used in preparation of silica (silica gel as well as powder), zeolites, activated carbon, silicon nitride, porous carbon, silicon carbide, preparation of silicon chip and also making of light weight construction materials, insulations, preparation of green catalysts, important constituent for preparation of lithium batteries, energy capacitor , grapheme and carbon capture. It has various other important applications such as synthesis of silicones and it's alloys, synthesis of soluble silicate, synthesis of chemical based silicon,Filler for both natural as well as synthetic rubber (Pode,2016; Della *et al.*,2002; Naskarand Chatterjee, 2004; Sun and Tzong-Horng, 2004; Wang *et al.*,1998; Conradt *et al.*, 1992; Mohamed *et al.*,2015). There is not much awareness regarding properties and uses of Rice husk and hence they are not utilized judicially.

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Rice husk and its ash are very useful for domestic as well as industrial purpose and its utilization for various application can serves as solution for its disposal. In the present review paper our focus concentrated on composition and relevant applications of RH in various sectors.

Composition of rice husk

The composition of rice husk is described in table 1

Table 1 Composition of Rice Husk

S.NO	COMPOSITION	%
1	Hemicelluloses	24.3%,
2	Lignin	19.2%
3	Cellulose	34.4%
4	Ash	18.85%
5	Trace elements.	3.25 %

Hemicelluloses is one of the major source of xylose ,activated carbon,and silicon dioxide. The % elemental composition of Rice husk include- Hydrogen 8.80%, Silicon 9.01% , Carbon 37.05%, Nitrogen 11.06%, and Oxygen 35.03 % (Sarang *et al.*,2009). Silica is 17-25% in husk (Real *et al.,* 1996, Conradt *et al.,* 1992).

Table 2. Other properties of RH (Muthadhi *et al.*, 2007)

S.NO	COMPOSITION	%
1.	Bulk density	96-100kg/m^3
2	Hydrogen	4-5%
3	Ash	22.29%,
4	Sulphur	0.04-0.08%
5	Nitrogen	0.23-0.32%
6	Oxygen	31-37%
7	Hardness (Mohr's scale)	5-6

The composition of rice husk is affected by various factor such as different variety of rice, different type of fertilizer used for crop, geographic location of the area and soil structure of that region, and (Muntohar *et al.,* 2002).

Rice Husk Ash (RHA): Its Composition

Among all the Biomass fuels rice husk is high in ash content ie.14-25% .The amount of silica present in rice husk ash (RHA) range from 83-98% (Rozainee *et al.,* 2008; Pode,2016, Adam *et al.*,2006). Due to high content of silica, RHA is a valuable industrial material as it can be used for various industrial processes. X-ray fluorescence was used to determine chemical composition of RHA It was found to contain- SiO_2 89%, Al_2O_3 1.20%, C 18.24%, CaO 1%, K_2O 1.22%, Fe_2O_3 1.28% The ash properties are affected by different factors such as rate of heating, incinerating conditions (which includes duration of heating and temperature), and different burning methods (Mohamed *et al.*2015; Mansaray Ghaly1999, Govindarao,1980).

Rice Husk: Application: Rice husk has very different physical and chemical properties such as high silica and ash content, and therefore it find applications in various industrial and domestic processing. Most of review papers suggested and discussed that Rice husk can be used as fuel such as in parboiling process of rice, in furnaces, in brick kilns, and also it is very important raw material for the preparation of sodium silicate. It can also be used as polishing and cleaning agent for metal, synthesis of molecular sieve (Shwetha *et al.,* 2014; Singh, 2000; Ugheoke *et al.,* 2006).

The important applications of Rice husk are as follows:

Source of fuel

Rice husk works as very good source of biofuel. The RH has calorific value around 15218.21 KJ/Kg. The performance of rice husk as fuel is comparable to that of traditional fuels. Hence RH is cheaper fuel than coal (Velupillai *et al.,*1997; Yadav and Singh,2011). The heat energy is generated when direct gasification and combustion of rice husk is done. It finds application several processes where heat energy is required such as steam generation in parboiling of rice (Prasara and Grant, 2011; Yadav and Singh, 2011; Shwetha *et al.*,2014). It can also be used for generation of electricity. For example 1 tone of RH produces around 1 MWH electricity. The RH also serve as substitute of traditional fuel for household energy (Rozainee *et al.,* 2008). The following reaction is involved with rice husk as fuel with following reactant-(Monga *et al*,2015) 1 mole C, 0.3052 oxygen (O_2) , 0.6402 moles hydrogen (H_2), as follows.

$C+ + 0.3052\ O_2(g) + 0.6402\ H_2\ (g) + 2.0298\ NiO = CO_2(g) + 0.6402\ H_2O(g) + 2.0298\ Ni$

Major Source of silica as well as silicon based materials: Silica is the fundamental raw material that was widely used in many processes such as chromatography, adhesives, ceramics, vegetable oils and pharmaceuticals. Rice husk consist of high amount of silica, therefore it is a source for various silicon compounds such as Zeolites, silicon tetrachloride, silica, silicon nitride, silica, silicon carbide, and silicon(pure). It is also used for preparing a number of advanced engineering materials like elemental Si, Mg_2Si, Si_2N_2O, SiC, SiN, silanes (Karera *et al.*,1986; Acharya *et al.*,1980; Sun and Gong, 2001; Patil *et al.*,2014; Padhi and Patnaik, 1995; Soltani *et al.*,2014;). There is reaction between SiO_2 obtained from rice husk ash and NaOH is as follows (Della *et al.,* 2002).

$$ySiO_2 + 2xNaOH \rightarrow xNa_2O \cdot ySiO_2 + xH_2O$$

The silica gel can be produced by neutralization of sodium silicate ($xNa_2O \cdot ySiO_2$). The reaction is as follows (Real *et al.,* 1996)

$$xNa_2O \cdot ySiO_2 + xH_2SO4 \rightarrow ySiO_2 + xNa_2SO_4 + xH_2O$$

It has been observed that SiC (Si-SiC) has also been prepared from powdered mixture of rice husk ash-C-Mg according to following reaction (Niyomwas,2009).

$$2SiO_2(s) + C(s) + 4(Mg) = Si(s) + SiC(s) + 4MgO$$

The Silicon nitrate is produced by series of following reactions (Soltani *e tal.,* 2015)

$$SiO_2(s) + C(s) = SiO(g) + CO(g)$$

$$SiO_2(s) + CO(g) = SiO\ (g) + CO_2(g)$$

$$SiO(g) + 2/3N_2\ (g) = 1/3Si_3N_4\ (s) + \tfrac{1}{2}O_2\ (g)$$

The amorphous SiO_2 can be reduced to form silicon as shown in the reactions (Bose*et al.,* 1993)

$SiO_2 + 2Mg = Si + 2MgO + SiO_2$ (unreacted)

As Organic fertilizer: In the present changing environment, organic fertilizers are need of the hour in agriculture process. Rice Husk is being used as major source of an organic fertilizer. These fertilizers improve productivity and also increase water efficiency of the agricultural field (Badar and Qureshi, 2014; Ebaid, *et al.,* 2007; Govindarao 1980). Studies suggested that rice husk is used to improve absorption of various macro and micro elements such as nitrogen and other important nutrients which are directly responsible for increasing the efficiency of production and translocation of the dry matter content to agricultural field (Ebaid, *et al.,* 2007; El-Wehishy and El-Hafez, 1997; Awad, 2001; El-Refaee *et al.*,2006;). Further, the Rice Husk is also a potential source of potassium which is important for growth and yield of cow pea (Seran, Priyadharshini,2010). Conversion of rice husk into fertilizers is done through vermi-composting (Shak *et al.,* 2014; Lim *et al.,* 2012;).

As source of Fiber: Dietary and food: Right from the ancient times rice husk has been used as an important constituent in ruminant and poultry (Aderolu *et al.,* 2007; Shqueir *et al.,* 1989; Aderolu *et al.,* 2004). Rice husk consist of around 30% dietary fiber. It is used in food industry as it is rich in protein and minerals. The Enzymatic extraction of rice husk produces more fiber than any other chemical method (33.97% vs.67.53%)

$CO_2 + C = 2CO$

Used as an Adsorbent: The rice husk is insoluble in water due to high silica content, it also have effective chemical stability due to its structure (Lee *et al.,* 1994).Therefore it finds application in the purification of water and treatment of waste water. Rice husk sorbent can effectively remove various heavy metals such as Manganese, Iron, Lead, Copper, Cadmium (Yalcın and Sevin, 2000; Daifullah *et al.,* 2003; Munaf 2010). It also work as good adsorbent to remove different type of heavy metals, pollutants, dyes, pesticides, phenols, inorganic anions and organic compounds (Gupta *et al.,* 2006; Chauh *et al.,* 2005; Lata and Samadder,2014).

In Synthesis of bio-ethanol: Rice husk is used for the synthesis of Bioethanol which is solution to many problems such as energy, environment, economic faced by the world (Saha and Cotta, 2007; Srivastava, 2014). The Bio-ethanol can satisfy about one fifth of the global bio-fuel demand. The global potential level production of bio-ethanol is around 20.9 to GL per annum from RH (Nyachaka *et al.,* 2013).

Other uses

- SiO_2/C composites from RH are highly porous and designed by heating pellets composed of RH powders in different sizes (Warati *et al.,* 2006).
- Used in adsorption of direct dyes from aqueous solution (Wahab*et al.,* 2005).
- RH has good binding property, which decreases the formation of cracks in the material. Therefore it is utilized for synthesis of pottery products especially biodegradable (Ammara *et al.,* 2012).
- RH has been used as important ingredient for making building materials, panel board, fillers in plastics, insulating board material, filling material, (Farooquea *et al.,* 2009).

Application of Rice Husk Ash (RHA): RHA is a valuable raw material for various industrial as well synthesis applications such as Polymer industry, adsorbent and heterogeneous catalysts, refractory industry, ceramic applications, cement industry, fillers of rubber, plastic composites, (Sevdalina *et al.,* 2012). Some of the other important industrial and domestic applications of RHA are discussed below:

Used as silica source: It has been noted that the presence of silica in rice husk has been known since long time around the world (Martin, 1938). Silica was a basic material that was widely used in different ways like chromatography column, adhesives, ceramics, pharmaceuticals etc. Rice husk ash (RHA) contained over 60% silica and it is economically feasible raw material for preparing silica gels as well as powder. RHA has become a major source for synthesis of silica (Patil *et al.,*2014; Supakorn *et al.,* 2009; Shelke *et al.,* 2010; Della *et al.,* 2002; Supitcha *et al.,* 2009; Singh *et al.,* 2008). Precipitated silica can be widely utilised in many of the industries such as tyre industry, cosmetics, electronics, ceramic, polymer material, paint industry, food industry, thickening agent in paints, reinforcing agent in rubber, thermal insulators, thyrotrophic agents, in toothpastes as a cleansing agent and composite-fillers (Rama-Rao *et al.,* 1989; Dongmin *et al.,* 2010). Some researchers have also prepared mesoporous and zeolites silica from rice husk ash. In recent studies sodium met silicate has been prepared by green and low cost method.

In Building materials (Cement and Concrete Industries): Among all the agricultural waste, rice husk ash is having highest percentage of silica and is considered as pozzolanic material. Pozzolanas are considered as siliceous and aluminous materials and possess no cementations property in itself. Rice husk ash is used as filler to enhance strength of concrete blocks (Cisse, and Laquerbe, 2000). As a replacement of Portland cement Lime pozzolana mixes with RHA are used (Mehta, 1977; Zhang *et al.,* 1996; Nicole *et al.,* 2000; Kartini, 2011; Ganesan *et al.,* 2008; Xu *et al.,* 2014). It has been observed that with the use of Rice Husk ash along with concrete increase compressive strngth, reduced permeability and the improved flexural strengths (Ganesan *et al.,* 2007; Zhang *et al.,* 1996; Ismaila, 1996;). Rice husk ash can also provide increased resistance to chemical attack, increased workability as well as durability of concrete material. (Coutinho, 2002)

As Filler in Polymer: RHA has been successfully utilized as filler in the various polymers such as polypropylene (Ismail,2002; Fuad *et al.,* 1995; Prema lal *et al.,* 2002;), polyethylene (Pantha pulakkal *et al.,* 2005; Cisse and Laquerbe, 2000), polystyrene (Ismail, 2003). Thermal degraded products of rice husk are often used as fillers in many polymers (Choi *et al.,* 2006; Saheb and Jog,1999), and polymeric composites (Prema lal *et al.,* 2003; Nassar *et al.,* 2007), paper, paint (Chandrasekhar *et al.,*2003) etc.

Vulcanization of Rubber: As an Additive: Addition of RHA as an additive with other coupling agents in natural rubber improves its mechanical properties. The presence of coupling agent in rubber as well as composites increase the mechanical

and physical strength, filler dispersion as well as crosslink density (Araya pranee *et al.,* 2005; Ismail *et al.,*2001; Siriwandena *et al.,* 2001;).This is also very good fillers for various epoxidized natural rubber compounds (Mehta *et al.,* 1995).

Synthesis of Refractory bricks: As compared to conventional clay bricks, the bricks prepared by mixing of rice husk ash (mixture bricks), have greater compressive strength. (Rahman 1988; Amin *et al.,* 2013).

Insect Pest Controller in stored foodstuffs: RHA is found to be effective in controlling the effect of insects and pests in stored food stuffs. Rice husk ash has been successfully used against *Callosobruchusmaculatus* (F) and *Sitophiluszeamais* (Mots) (Shazia *et al.,* 2006, Adebayo and Ibikunle,2014, Paneru and Shivakoti, 2000/2001). Rice husk ash has been found to be effective as an oil spill absorbent in water-proofing chemicals, as good flame retardants, and also carry insecticides and pesticides (Kumar *et al.,* 2012).It is reported that rice husk ash (RHA) is effective in keeping stored potatoes free from potato tuber moth (*Phthorimaeaoperculelle*) for around five months of storage.

In the water purification: In the present time of industrialization the contamination of water is a serious issue. Presence of Arsenic in drinking water is becoming a main health issue in today's scenario and more than 100 million people across the nation are suffering with the ill effect of drinking contaminated water. The removal of arsenic with the use of RHA as an adsorbent has been reported by various researchers (Malhotra *et al.,* 2013; Saha *et al.,* 2002; Adams Bhagavanulu, 2015). RHA is very effective adsorbent for the adsorption of various heavy metal such as lead, mercury from aqueous water (Feng *et al.,* 2004). It has also been found effective in removing Methylene blue, humic acid from waste water (Sharma *et al.,* 2010; Imyim *et al.,* 2010). As silica is the main constituent in rice husk ash, the ion- exchange reaction occurs on surface of silica with the substitution of protons by the metal ions as shown in the following reaction (Masoud *et al.,* 2012)

$$xM^{+n} + x(=SiOH)^{(n-x)} + xH^{+}$$

M^{n+}= metal ion with n^{+}charge
SiOH=group Silanol on the SiO_2 surface.
xH^{+}=number of protons released during the reaction

Ceramic Industries: RHA used in ceramic glazes (Bondioli *et al.,*2010). Rice husk ash is an important ingredient in synthesis of (Zr, Pr) SiO_4 pigment, Si_2N_2O, Si_3N_4 and SiC, mullite ($3Al_2O_3 \cdot 2SiO_2$), SiO_2 porous ceramic materials, cordierite ceramics (Chen *et al.,* 2014; Serra *et al.,*2015; Bondioli *et al.,* 2007; Padhi and Patnaik, 1995)

Synthesis of Nano-particles: RHA has been found to be efficiently and effectively used in preparation of silica nano-particles through green and eco-friendly route (Premaratne *et al.,* 2013; Thuadaij and Nuntiya, 2008; Sankar *et al.,* 2016). It is also investigated that SiO_2 and SiC nano wires, and $SiO_2/CaCO_3$ nanocomposite can be successfully synthesized from RHA (Morsy *et al.,* 2014; Pukird *et al.,* 2009). Nanosilica has been successfully synthesised from solution of sodium silicate by precipitation method according to following reaction:

$$SiO_2\ (Ash) + 2NaOH\ (Caustic\ soda) \rightarrow Na_2SiO_3\ (Sodium\ silicate) + H_2O\ (Water)$$

The silica particles were also prepared by using sodium silicate by using sulfuric acid as catalyst by the following reaction (Rafiee *et al.,* 2012).

$$Na_2SiO_3 + H_2SO_4 \rightarrow SiO_2 + Na_2SO_4 + H_2O.$$

Silica nano-particles(SNPs) are usually utilized for different types of applications such as industrial manufacturing, packaging, composite of ceramic, drug delivery, biosensing, adsorption, and also as catalyst for various processes (Ghorbani *et al.,* 2015).

In Renewable energy: Biodiesel are one of the green alternative energy sources which is produced from either biological or natural resources which include agricultural and food waste. It has been found that its physical and chemical properties are similar with diesel oil without any modification in engine (de mello *et al.,* 2017).Biodiesel has many benefits such as cheapness, non-toxic, biodegradability and eco-friendly (Taufiq-yap *et al.,* 2017)

Other important uses: RHA is also found to be an effective use as pigment extender in emulsion paints (Ossi and Dilim,2015, Igwebike-Ossi and Dilim,2014).RHA being a siliceous material, it is also used as sorbents for desulfurization process in small-scale industrial boilers. It has been found that RHA also successful in marine diesels pill clean-up (Dahlan *et al.,* 2006; Bazargan *et al.,*2014).Further, this also discover that it very effective oil absorbent for absorption of vacuum pump oil. It also purify biodiesel from waste frying oil (Tatum and Winter, 1997; Chou *et al.,* 2001;Manique*et al.,* 2012). A novel and low cost application of RHA is utilization in pre concentration of gold (Nakbanpote *et al.,* 2000; Nakbanpote *et al.,* 2002). Silica extracted from RHA is a successful corrosion inhibitor for carbon steel (Awizar*et al.,* 2013)**.** In many developing countries, it is regularly used for reduce the fatty acid content from frying oils (Chou *et al.,* 2007).

Conclusion

Rice husk and rice husk ash is an agricultural waste which is freely available at a nominal price. With the development of new research methods, systematic and potential application of RH and RHA for manufacturing new materials could solve many issues related to its disposal and burning in field which is responsible for pollution. This process could bring economic feasibility in waste treatments. Presence of more amount of silica content in RH as compared to other agricultural waste provide an opportunity to explore direct and indirect applications in different field, which makes it an important market value product and can give a good economic return to the producer. Effective application of RH in fuel/electricity generation, bioethanol production provides an opportunity to transfer agriculture waste product to valuable/ renewable energy source for various industries. Rice husk ash is considered to be promising as Pozzolanic material and also as an adsorbent. Synthesis of silica nano-particles and their application in various fields and industries makes it an important raw material for nanotechnology. The use of agriculture waste as a source of renewable and sustainable energy source has a great potential as low-cost raw material for production of various valuable material. Sustainable use of rice

husk and its ash could help in increasing agricultural economy and can also contribute towards rural development of our country.

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